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D7H-Test Results*

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Data was reduced from the voltage-time relations stored in files D7H001 to D7H090 on HP1000. The I-B calibration curve is included in Fig. 1. The data base is shown in Table 1 and can be used by the 9845B. The data include the quench location, Q_2 layer 1 top, Q_3 layer 1 bottom and the quench current and its normalized value with respect to short sample, I_c = 4920A at 4.4 K, I_c = 6710 A at 1.8 K. The resistance (/cm) was calculated using the propogation time according to the voltage change across the measured sections. The conductor potential length are $L_{5,9}$ = 48.6 cm, $L_{6,10}$ = 17.9 cm, $L_{7,\ 11}$ = 40.6 cm (Fig. 8). The turn to turn velocity V_t was calculated dividing the nominal turn to turn distance (58 mil) by the propagation time (Trans. Time). The quench time T_q was measured from the time the resistive rise starts until the energy extraction system fires. Figures 2-6 are plots of the data base. The time to energy extracton can be estimated as:

$$T_q = \frac{Vo}{2IR'V} \tag{1}$$

where:

Vo = trip voltage

R' = resistance per unit length

V = velocity

I = current

For a propagation which is axial only. The discontinuity in T_q (Fig. 4) is due to a drop in the propagation velocity when the temperature was

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lowered from 4.4 K to 1.8 K. Assuming Vo = .25 volt and using I, R', V values from the data base, equation 1 is plotted in Fig 5.

Resistivity

The resistance per unit length at the normal state is plotted in Fig. 6. The values at the magnet ends vary from .9 to 1.3 /cm between 4000A and 7000 A and the straight section values are about 15 percent higher. For a 23 strand cable at 27 mil strand diameter and 1.8/1 S.C/copper ratio the total copper cross section area is 5.46×10^{-2} cm^2. Assuming all the current had been switched to the copper the resistivity is 4.9×10^{-8} – 7.1×10^{-8} (cm) and the corresponding resistivity ratio is therefore RRR = 35 to 20.

The alteration of the quench location between the halves of the inner shell is plotted in Fig.7 and the quench origin around the first inner turn is plotted in Fig. 8. <u>All</u> quenches occured around the first turn! (The only exceptions were very fast ramp rates).

Temperature Rise

After the normal zone propagates through a measured section, its resistance keeps increasing due to a temperature increase. The resistance rise with respect to time is observed to be linear (Fig. 9) in the time scale before the energy extraction. Converting this values to a resistivity rise the results are given in Table 2. A simplified energy balance result in an approximate temperature-time relation.

$$MC\frac{dT}{dt} = I^2R \qquad (2)$$

$M = {}_d\, lA$ (${}_d$ = density, l = length, A = crossection area)

$R = {}_r\, l/A$ (${}_r$= resistivity)

The total mass assumes copper only (e.g. no liquid participation).

Equation (2) reduces to

$$C \frac{dT}{dt} = \frac{r}{d} \frac{I^2}{A^2}$$

$$CdT = \frac{I^2}{A^2} \frac{1}{d} \quad {}_{r}dt$$

The experiment shows that $\;{}_{r} = {}_{r}(t) = t$

therefore,

$$CdT = \frac{\quad}{2 \;{}_{d}} \quad \frac{It}{A}^{\;2} \qquad (3)$$

Equation (3) was solved for 2 nominal cases using $A = 5.46 \times {}^{-10}\ cm^2$; ${}_{d} = 8.94\ (gr/cm^3)$

1. File = D7H008 (4.4 K)

   $I = 4220$ A;

   $= 1.1 \times 10^{-6}$ -cm/sec

   $CdT = 3.675 \times 10^{-4}.t^2$ (t = msec)

2. File = D7H061 (2.0 K)

   $I = 6340$ A;

   $= 2.46 \times 10^{-6}$ -cm/sec

   $CdT = 1.855 \times 10^{-3} \,.\, t^2$ (t = msec)

The result from the two cases using integral values of specific heat for copper are shown in Fig. 10.

Magnet Rate Dependance and Losses

The magnet was ramped at various rates and the quench field recorded. Repeating the test both in the He I and He II result in the relations shown in Fig. 11. The normalized field data were then fitted to a parabolic relation and plotted in Fig. 12.

Using our standard procedure in He II to determine energy losses the average heat flux generated during a cycle is plotted in Fig. 13 for a number of different field rates.